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A Study on Reduction of CO_2 Concentration in Underground Mine

Swaraj Mallick[1], Nadia Mahjabin[2]
[1,2]Department of Petroleum and Mining Engineering, Chittagong University of Engineering and Technology, Chattogram-4349, Bangladesh
E-mail: swarajpranta0@gmail.com, nadia.pme11@cuet.ac.bd

Abstract

Miners' health and productivity efficiency of a mine are at risk due to rising CO_2 concentrations in underground mines. This study aims to use the mine ventilation system to lower the concentration of the relevant gas. It uses an analytical and simulation technique to evaluate the impact of the ventilation system on mine air quality. To achieve the goal, the study first gathers data on air concentration at random, then uses fuzzy logic to determine the concentration and later, compares the results to a standard value (TLV). The simulated model was created using Ventsim simulation software, and the outcomes are shown graphically. According to the study, the CO_2 level may be manageable by increasing the air flow rate. For example, a flow rate of 3.41 ft3/min can lower the CO2 level by 0.625% from its original value of 0.8%. The study advises that the carbon capture and sequestration technology be another potential way to help with this issue. It also indicates that the heat flow rate and the percentage of contaminants be considered when thinking about mine ventilation systems as a potential solution to improve the air quality.

Keywords: Underground mine ventilation, mine gas, CO_2 concentration, Ventsim.

1. Introduction

To maximize productivity in a mine, the working environment, worker's health and safety must be properly maintained. CO_2 is a mine gas that can hold heat, is heavier than O_2, and causes headaches, vertigo, and difficulty breathing [1-3]. Thus, it is necessary to continuously monitor the CO_2 concentration to ensure a safe working environment. For the mine area, a concentration of 0.3% of CO_2 is appropriate [1,4]. In any mine, where workers are required to pass through, the air quality must contain no less than 19% oxygen and no more than 0.5% carbon dioxide, or any other noxious gas in amounts that could endanger human health [4,5]. Thus, certain procedures are required to keep the CO_2 concentration stable. Researchers suggest that carbon capture storage (CCS) and ventilation can be utilized to achieve this goal [6-9].

Ensuring enough ventilation is crucial for improving air quality in underground mining because it helps to maintain a safe and healthy working environment for miners by regulating the quantities of air contaminants, such as gases, dust, and fumes [10]. Adequate ventilation also affects the temperature and humidity of the mine area.

To combat climate change, carbon dioxide (CO_2) emitted from factories and power plants and other industrial operations is absorbed and stored instead of being released into the environment [6]. The goal of the technique known as CCS, or carbon capture and storage, is to collect the emissions of carbon dioxide (CO_2) from industrial operations and store them underground so that they won't be released into the atmosphere [7,8]. While CCS can be useful in lowering CO_2 emissions from power stations and other stationary sources, it might not be a feasible solution in underground mines. Hybrid life cycle assessment compares and evaluates the life cycle environmental impacts of producing electricity from coal and natural gas using different carbon capture and storage (CCS) technologies, such as post-combustion, pre-combustion, or oxyfuel capture, pipeline CO2 transport, and geological storage [9, 10]. Plants with a capture efficiency of 85–96% can reduce net greenhouse gas emissions by 64–77%, depending on the technology in use [6]. When extra life cycle effects are considered, there are significant trade-offs associated with freshwater eutrophication and poisoning potential. Effects on freshwater eutrophication, human ecotoxicity, and terrestrial ecotoxicity range from 40–75%, 60–120%, and 60–200%, respectively, over a wide range of technologies [9]. The post-combustion process increases the potential for freshwater ecotoxicity by a factor of two to four [11,12]. For coal-fired power plants, the increase in toxicity for pre-combustion systems is 40–80%, and for gas-fired power plants, it is 50–90% [12]. The energy requirement

for the air separation unit is the key factor influencing the oxyfuel approach's increased effects, which results in an increase in different toxicity potentials of 35-70% for coal and 60-105% for natural gas systems. The study tries to find out the efficacy of increasing the quantity of fresh air below the surface in reducing carbon level.

2. Research Framework

The study has been conducted in three folds. First, air flow data from anemometer has been collected. Then data are incorporated in fuzzy logic to see the variations of calculated data with TLV. The flow rate (Q) vs. CO2 concentration graph illustrates the results and offers insight into the experiment. Next, the feasibility of applying CCS technology in underground mine has been justified against available data and real filed cases. Finally, both results have been compared and the best alternative has been suggested. Steps are displayed in Fig. 1.

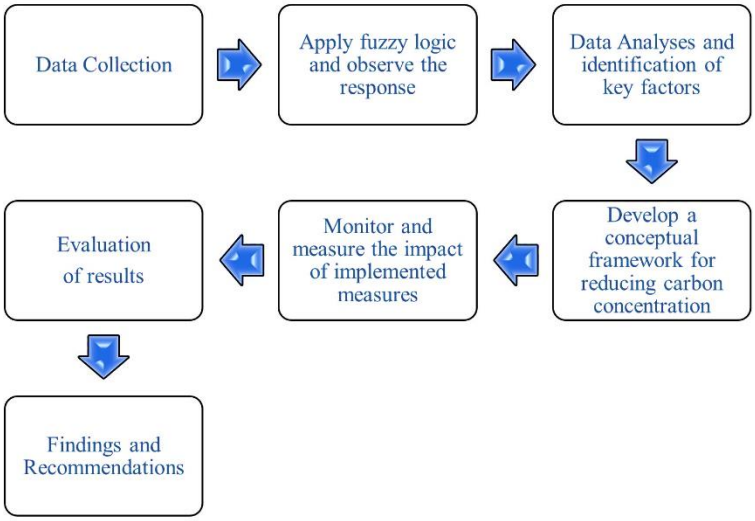


Fig.1. Research design of the study

2.1 Working Principle

At first, a simulated network model of an underground mine has been developed. After that, mine fans have been placed in the model which show CO_2 concentration level. Then by changing the rpm value of mine fans the impact on CO_2 concentration level has been observed. The working procedure has been described in Fig.2.

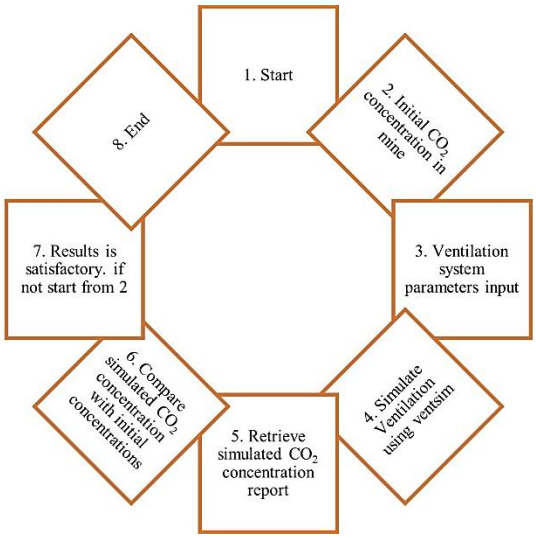


Fig.2. Workflow in Ventsim software

2.2 Assessment of Air Quality through Analytical Method

Empirical equations have been applied to calculate the air flow rate. Value of the initial and simulated CO_2 concentrations, the volume or area being ventilated and the time period over which the airflow occurs, is needed to calculate the concentration value. It is expressed by air changes per hour formula (Eq.1). That is

$$ACH = (Q/V) *60 \quad \text{(Eq.1)}$$

Where, ACH = Air changes per hour, Q = Flow rate of fresh air, ft^3/min (CFM), V = Volume of the space, ft^3. The concentration value of CO_2, given by the anemometer, needs to be checked, whether it is in the range of TLV value. If, it's not in the TLV value then it will be used for CO_2 concentration's initial value. As it is difficult to get an ideal mine air gas concentration, four different values of CO_2 concentration (0.8%, 0.6%, 0.5789%, 0.4%.) have been chosen randomly over TLV value for this study. The values have been selected such that they are higher than the TLV of CO_2 concentration which is 0.3 [2]. Then the fan rpm has been changed to lower the CO_2 level below the standard and Eq. 2 is used to calculate the reduction rate.

$$CO_2 \text{ reduction} = (CO_2 \text{ initial} - CO_2 \text{ final})/CO_2 \text{ initial} \quad \text{(Eq.2)}$$

After CO_2 reduction percentage is calculated, it can be used to determine flow rate of fresh air that needs to be supplied into the mine area.

$$Q = (CO_2 \text{ reduction} \times CO_2 \text{ initial} \times V) \div (60 \times 28.97) \quad \text{(Eq.3)}$$

After getting the value of flow rate in CFM, ACH can be calculated too. The changes in flow rate flow rate help to vary fans characteristics like fan size, air quantity [5] which will aid in adequate ventilation.

3. Result and discussion

For machine reading, four data have been selected randomly between the range of 0 to 1. Then fuzzy logic has been applied to observe the response on the increase/ decrease in the CO_2 level which has been listed in Table 1.

Table.1. Increased rate of CO_2 compared to machine value

Machine Value (%)	Increased Rate (%)
0.8	300
0.6	200
0.5789	189.45
0.4	100

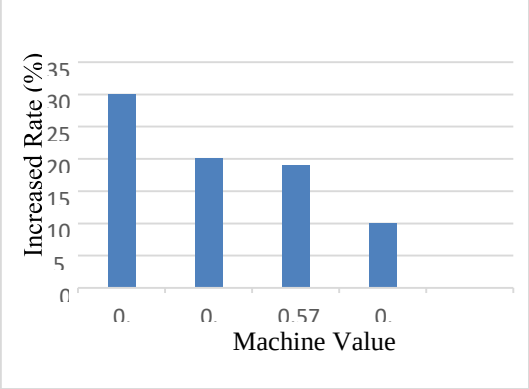


Fig. 3. CO_2 increased rate vs machine value

As seen from the Fig. 3, an increase in the emission of CO_2 gas from the machine by 8%, can increase the CO_2 level in the atmosphere by 300%.

Adequate Ventilation

To reduce the CO_2 level at its TLV, the machine data is incorporated in the fuzzy logic again, and air quantity has been increased. The results are displayed a remarkable decrease in the CO_2 level as seen from Table 2.

Table.2: Reduction value result.

CO_2 Initial (%)	CO_2 Final (%)	CO_2 Reduction (%)
0.8	0.3	0.625
0.6	0.3	0.5
0.5789	0.3	0.481
0.4	0.3	0.25

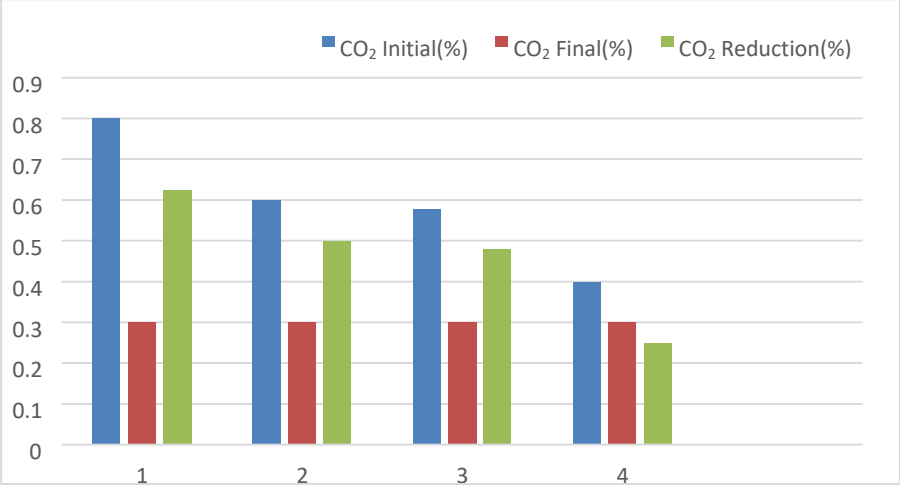


Fig.4. CO_2 reduction rate

The calculation has been performed for four initial values of CO_2, and the reduction in the CO_2 level has been shown through green bar in Fig.4. The %CO_2 for three cases has been marked in three different colors and values are represented in Y axis. Next, the calculation has been performed to measure the airflow rate as presented in Table 3.

Table 3: Calculated value of flow rate with CO_2 initial and CO_2 reduction.

CO_2 Initial (%)	CO_2 Reduction (%)	Flow Rate, Q(CFM)
0.8	0.625	3.41
0.6	0.5	2.04
0.5789	0.481	1.9
0.4	0.25	0.68

Fig. 5 reflects the results of Table 3. The results show that to reduce the CO_2 level from 0.8% to the standard value, a minimum airflow rate of 3.41 ft^3/min is required and the quantity reduces at a lower % of CO_2 emission from the machine.

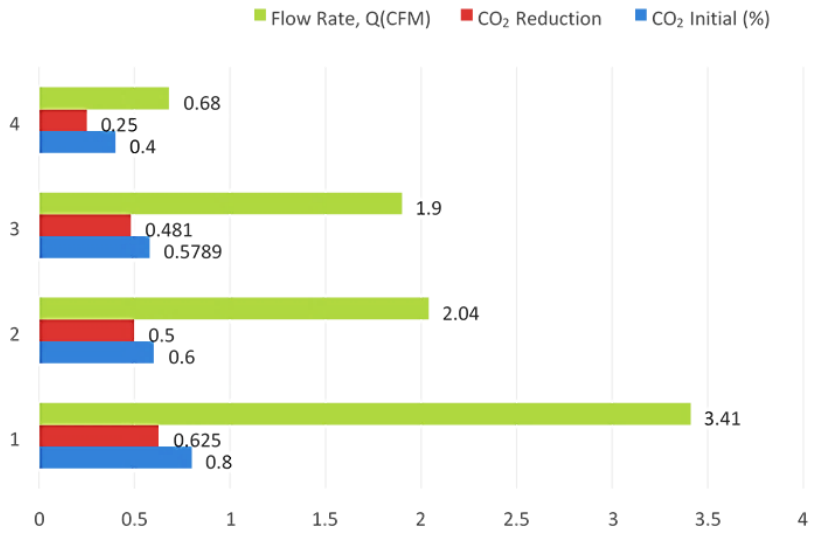


Fig.5. Q vs CO_2 reduction and initial value

The simulated model suggested for the study has been presented in Fig. 6

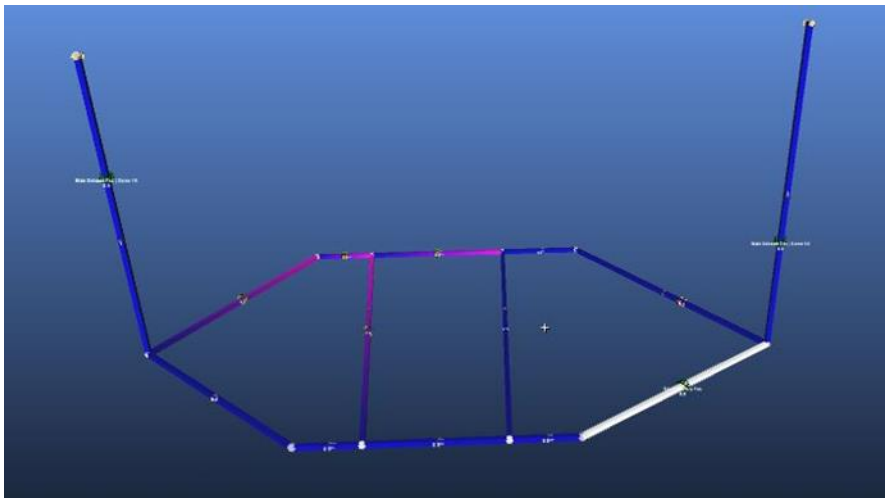


Fig. 6: Ventilation Network Model for the study

CCS Techniques

The ability of a particular field to depose CO_2, collection of CO_2 from large stationary source, and transportation to a storage site are the three factors that determine the affectability of the CCS technique [13]. One probable source of CO_2 in underground mines is the operation of vehicles, surface plants, and caving. One way to reduce the amount of carbon in the atmosphere can be to gather CO2 from these locations and then deposit it in deep geologic layers. But to assess the feasibility of the proposition, a thorough risk and cost analysis is mandatory [14], which is beyond the scope of this study since it needs detailed experimental data.

4. Discussion

In this study, the application of mine ventilation followed by the application of air flow has been considered for reducing CO_2 concentration in underground mine. The study found that as the concentration has been increased, more airflow is required to reduce the carbon level. Parameters like percent of contaminants,

heat flow through the mine etc have not been considered in this study that are required for the proper calculation. Since the experiment has been performed in simulation environment some data have been anticipated. These are the drawback of the study. The study suggest that by increasing the airflow rate the CO_2 concentration can be maintained at a specified level like to minimize the rate from 0.4 to 0.25, 0.68 CFM air flow rate is required and to reduce a high % of CO_2, a greater amount of air flow rate is required.

5. Conclusion

Based on the findings, following suggestions have been proposed

- **Better Airflow Distribution:** According to the study, it is feasible to enhance the air concentration flow throughout the underground mine by arranging and configuring the mine ventilation systems correctly. This could lead to improved mining conditions, reduced pollution, and better air quality. Fresh air will aid to enter the mine area with an improved mine ventilation system, and contaminants in the air will be expelled along with the ventilated air.
- **Feasibility of CCS Technologies:** This concept is still under consideration. For this project to succeed, cost-effectiveness, public acceptance, and environmental impact must all be considered. No work has been done yet to lower the carbon concentration in underground mines using this method so researcher can think on this problem.

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